Bulletin by Alexander Graham Bell, July 22, 1901

1901, July 22 Monday At Beinn Bhreagh. A FEW THOUGHTS UPON KITES.

Umbrella ribs are now made of tin instead of whalebone. Tin ribs of this sort would form an admirable framework for kites.

The cellular type of kite is not well adapted for storage on board of a boat. It would be much better if a fan shaped kite could be adopted for sailing a boat that could be folded up like a fan and stored away. In this connection I am much struck by the steadiness of the Japanese fan shaped kite. Perhaps a one-celled kite of this kind may fly well with the string attached in front of the kite on a fixed point. If such a kite would fly bamboo rods would be just the thing to make the supporting ribs. I have bamboo rods about fifteen feet long. Three or four of these radiating from a center like a fan would support an enormous sail area fit to tow a man-of-war, but they wouldn't float well. Inclined to think that for large kites for sailing purposes metal ribs would be better consisting of pipes of large diameter and quite thin metal. They would be much lighter than wood, and would float well in the water if hermetically sealed.

1901, July 31 Wednesday At Beinn Bhreagh. BAMBOO.

The properties of bamboo are contradictory and extraordinary. It is very hard and yet soft, you can cut it with a pen knife; very tough and extremely elastic; a kite framework made of bamboo could hardly be broken. I am surprised at the ease with which the wood can be worked, had the idea that it would require special tools. Amused myself yesterday afternoon in whittling with my pen knife, found no difficulty whatever in cutting it and shaping it.

The hard part seems to be confined to an outside skin of very slight thickness; the inner part is almost as easily cut as a piece of pine. When we make kite-frames of pine or spruce, we are quite accustomed to sticks here and there giving way. If the kite comes down with a bump, something has broken, awind squall too, will smash a cell. If the kite framework could be made of bamboo none of the ordinary accidents to which we are accustomed would break it.

Another contradiction:— Bamboo is very heavy, and yet light, specifically heavy and yet it can be used in such thin pieces as to constitute a very light framework.

Yesterday I cut away the soft backing from the hard shell, and then found that though the hard shell resisted cutting transversely it could be split up with a pen knife into fine hairs.

Altogether I consider that bamboo has very remarkable properties, and its admirably adapted to make light, tough, 2 elastic framework for a kite. I do not know anything better, but we require to learn how to work it. It lacks, however, rigidity. If we use a piece sufficiently thick to be rigid it is very heavy in comparison with other woods.

1901, October 26 Saturday At Beinn Bhreagh.

SURFACE MATERIALS.

Weight per square meter.

Celluloid (Kodak Film) 76 grs.

White Cotton (used for our kite surfaces) 152 grs.

Red Cotton (used for our kite surfaces) 144 grs.

Red Cotton (used for our kite surfaces) 160 grs.

Celluloid film (heavy) 350 grs.

Oil cloth (table cover material) 543 grs.

Aluminum (sheet) 1051 grs.

Brass foil 1307 grs.

Sheet copper 1729 grs.

Tin plate 2517 grs.

Tin plate 2862 grs.

FRAME MATERIALS.

Weight per meter length.

Steel (fine piano wire used for high notes) 1 grm.

(about 0.05 cm. diameter)

Aluminum wire (about 0.15 cm. diameter) 2 grms.

Brass wire (about 0.1 cm. diameter springy) 3 grms.

Iron wire (about 0.05 cm. diameter used for fastening the corks of bottles) 3 grms.

Iron wire (stove-pipe wire) (about 0.15 cm. diameter) 5 grms.

Brass wire (about 0.1 cm. diameter medium hard) 5 grms.

Steel (piano wire) (about 0.15 cm. diameter stout and strong 8 grms.

Pine stick (about 0.5 cm. diameter sq. cross section; a 50 centimeter length broke with weight of 15 grms. suspended from center) 10 grms.

Spruce stcik(about 0.5 cm. diameter, square cross section Broke with weight of 2315 grms. suspended from center of a stick 50 cm. long) 12 grms.

Pine sticks used in kites 100 × 0.5 × 0.5 cm. 11 grms.

Pine stick used in kite (calculation made from 39 sticks each 50 × 0.5 × 0.5 cm. and weighing altogether 224 grms. 11 grms.

Iron wire (about 0.25 cm. diameter) 19 grms.

Pine stick (100 × 1 × 1) 40 grms.

Spruce stick (100 × 1 × 1) 44 grms.

Brass rod (about 0.25 cm. diameter 64 grms.

Steel rod (100 × 0.5 × 0.5 sq. cross section 187 grms.

3

Pine wood (100 × 3 × 3 sq. cross section) 427 grms

Brass Pipe (100 long, about 2.5 cm. diameter) 466 grms

Aluminum pipe (100 long, about 1.5 cm. diameter) 145 grms

The following weights are calculated from a Table of Specific Gravity, given in Ganot's Physics p. 107).

Yellow pine (100 × 0.5 × 0.5) 16 grms

Oak (100 × 0.5 × 0.5) 21 grms

Elm (100 × 0.5 × 0.5) 20 grms

Beech (100 × 0.5 × 0.5) 22 grms

Bronze (100 × 0.1 × 0.1) 9 grms

German Silver (100 × 0.1 × 0.1) 8 grms

Aluminum (100 × 0.1 × 0.1) 3 rgms

1901, September 28 Saturday At Beinn Bhreagh

A pipe 2 ½ cm. diameter weighs 266 grs

A pipe 5 cm. diameter weighs 885 "

A pipe 10 cm. diameter weighs 1127 "

(Three pipes like the above all 200 cm. long and made of wood 2 millimeters thick.

A pipe 2 ½ cm. diameter weighs 138 grs

A pipe 5 cm. diameter weighs 333 "

A pipe 10 cm. diameter weighs 802 "

(Three pipes like the above of triangular cross-section 200 cm. long made of pine 2 millimeters thick. One 2 ½ another 5 and another 10 cm. wide.)

1901, October 22 Tuesday At Beinn Bhreagh

FLYING WEIGHT OF LIGHT KITE.

(Weight per square meter of wing surface).

Cloth 150 grams

Framework 250 grams

Total 400 grams

1901, October 22 Tuesday At Beinn Bhreagh

In Davis's Meteorology p. 94, a Table of wind velocity is given, with pressure on square foot, and square meter of surface opposed normally to it. From this it appears that with wind velocity of 5 m. per second a square meter of surface received a pressure of 3, 150 grams. Our kites can sustain easily a weight of one third of this. Theyr are capable of supporting much more, but would then be heavy flyers. The following is Davis's Table:—

4 SCALE TERMS MILES PER HOUR METERS PER SECOND LBS. PER SQ. FT. KILOS. PER SQ. M. 0 Calm 0 0 0 0 1 Very Light Brz 2 1 0.03 0.15 2 Gentle breeze 7 or less 3 or less 0.23(-) 1.13(-) 3 Fresh breeze 11 5 0.64 3.15 4 Strong wind 18 or ore 8 or more 1.62(+) 7.97(+) 5 High wind 27 12 3.64 17.9 6 Gale 36 16 6.48 31.9 7 Strong gale 45 20 10.12 49.8 8 Violent gale 58 26 17.12 84.2 9 Hurricane 76 34 29.26 143.9 10 Most violent 95 42 45.12 222.0 Hurricane

(From Davis's elementary meteorology, paragraph 18, p.194).

1901, October 22 Tuesday At Beinn Bhreagh.

I am constantly needing to translate miles per hour into feet per sec. or meters per sec. Have been making a calculation to get some easy way of remembering the relation. 1 mile per hour is equivalent to 1.4666 ft. per sec., approximately 1 ½ feet per second. This gives the rule:—ADD ON HALF THE NUMBER OF MILES AND CALL THE ANSWER FEET.

For example:— 10 mile per hour, how many feet per sec.? 10 + 5 = 15. (15 ft. per sec., approximately).

Again 1 mile per hour is equivalent to 50 cm. per sec., (Approximately), or ½ a meter. This gives the rule HALVE THE NUMBER OF MILES AND CALL THEM METERS PER SECOND.

For example:— 10 miles and hour, how many meters per sec.? 10÷2 = 5. (5 meters per sec.)

These rules can easily be remembered, and will enable me to calculate the number of feet or meters per sec. when given the velocity in miles, or vice versa. The results are not exactly correct, but are so nearly so that they will do for approximations to the truth. The following table will show how near the rule comes for feet per second:—

MILES PER HOUR FEET PER SECOND (by calculation) FEET PER SECOND (By rule) 1 1.46 1.5 2 2.93 3.0 3 4.49 4.5 4 5.86 6.0 5 7.33 7.5 6 8.99 9.0 7 10.26 10.5 8 11.73 12.0 9 13.49 13.5 10 14.66 15.0 20 29.33 30.0 30 44.99 45.0 40 58.66 60.0 5

1901, Nov. 29 Friday At 1331 Conn. Ave.

(Copied from Home Notes, 1901, Nov. 2, pp. 22,24,26,28).

1 METER CELLED COMPOUND KITE OF UNIT CELL 25cm.

Length of KITE No. of tiers of cells No. of cells. WEIGHT kgs. SURFACE sq.m. Weight available for strengthening frm.w'k. Load at 400 gms. per sq.m. 1 meter 4 40 1.3 3.75 166.6 gms. 1.5 kgms. 2 meters 8 80 2.6 7.50 333.3 gms. 3.0 kgms. 3 meters 12 120 3.9 11.25 499.9 gms. 4.5 kgms. 4 meters 16 160 5.3 15.00 666.6 gms. 6.0 kgms.

2 METER CELLED KITE (composed of 25 cm. cells.)

Length of KITE No. of layers of cells No. of unit cells WEIGHT in kgms. SURFACE in SQ.M. Wt. Available for strengthening fm.w'k, kgms. Load at 400 gms. per Sq.m. 25 cm. 1 36 1.999 3.375 0.150 1.35 kgs, 1 meter 4 144 4.799 13.5 0.6 kgms. 5.4 kgs. 2 m. 8 288 9.599 27.0 1.2 “ 10.8 kgs. 4 m. 16 576 19.199 54.0 2.4 “ 21.6 kgs. 6 m. 24 864 28.799 81.0 3.6 “ 64.8 kgs. 8 m. 32 1152 38.399 108.0 4.8 “ 129.6 kgs. 6

3 METER CELLED KITE (composed of 25 cm. cells).

LENGTH of KITE No. of layers of cells No. of unit cells WEIGHT in KGMS. SURFACE in sq.m. Wt. available for strengthening framework in kgms. LOAD at 400 gms. per sq.m. in kils, 25 cm. 1 78 2.6 7.3125 0.325 kgms. 2.925 kgs. 1 m. 4 312 10.4 29.25 1.300 kgms. 11.700 kgs. 3 m. 12 936 31.2 87.75 3.900 " 35.100 " 6 m. 24 1872 62.4 175.5 7.800 " 70.200 kgs. 9 m. 36 2808 93.6 263.25 11.700 " 105.300 " 12 m. 48 3744 124.8 351.0 15.600 " 160.400 "

4 METER CELLED KITE (Composed of 25 cm. cells).

LENGTH of KITE No. of layers of cells No. of 25 cm. cells WEIGHT in kgms. SURFACE in sq.m. Wt. Available for strengthening f'm. W'K LOAD at 400 gms. per sq.m. 25 cm. 1 136 4.533 12.75 0.576 kgms. 5.100 kgs. 1 m. 4 544 18.132 51.00 2.268 kgms. 20.400 kgs. 4 m. 16 2176 72.528 204.00 9.072 " 81.6 " 8 m. 32 4352 145.056 408.00 18.144 " 163.2 " 12 m. 48 6528 217.584 612.00 21.216 " 244.8 " 16 m. 64 8704 290.112 816.00 36.288 " 326.4 " 7

HEXAGONAL KITE

LENGTH of KITE No. of layers of cells No. of Unit cells. WEIGHT in kgms. SURFACE in sq. m. Wt. available for strengthening f'm w'k. LOAD at 400 gms. per sq.m. 25 cm. 1 216 7.2 20.25 0.900 kgms. 8.100 kgs. 1 meter 4 864 28.8 81.00 3.600 kgms. 32.400 kgs. 4 meters 16 3456 115.2 324.00 14.400 " 129.600 " 8 meters 32 6912 230.4 648.00 28.800 " 259.200 " 12 meters 48 10368 345.6 972.00 43.200 " 388.800 " 16 meters 64 13824 460.8 1296.00 57.600 " 518.400 " 8

1902, Feb. 17 Monday At 1331 Conn. Ave.

The following table will save much unnecessary labor in calculating flying weights and absolute weights of given aeroplanes:—

The following diagram shows graphically the relative sizes of the aeroplanes referred to above:—

9

A light kite should not weigh more than 400 gms. per sq. Metre of surface. A compound kite should consist of light cells with a skeleton of strong material. The whole compound structure to weigh not more than 400 gms. per sq. metre of surface.

I find that it is practicable to make the light cellular part of material weighing about 300 gms. per sq. metre of surface, leaving 100 gms. per sq. metre of surface for the material of the stronger framework, or skeleton (comparing a compound kite with a living creature the strong framework corresponds to the bony skeleton of the creature, the cellular structure to the flesh and blood). The material composing the flat surfaces of the aeroplanes need not weigh more than 100 gms. per sq. metre of surface. Closely woven silk weighs less, cotton and linen fabrics can also be obtained of sufficient closeness to serve the purpose at about 100 gms. per sq. metre. Celluloid and aluminum, in thin sheets, that would answer the purpose can also be obtained at less than 100 gms. per sq. metre of surface.

Allowing then 100 gms. per sq. metre for the aeroplane surfaces themselves, this leaves 200 gms. per sq. metre available for the light framework necessary to keep the surfaces stretched and in position. We obtain then the following theoretical distribution of weights:—

Light framework 200 gms. per sq. M. of wing surface.

Aeroplane surfaces 100 gms. per sq. M. of wing surface.

Strong framework 100 gms. per sq. M. of wing surface.

Total Kite 400 gms. per sq. M. of wing surface.

10

In utilizing the table, on p. 561 it will be well to remember that we can calculate the cubical contents of the material employed by dividing its weight in grams by the figure expressing its specific gravity. I find it safe to consider wood (of all ordinary kinds) as weighing half as much as water or having a specific gravity of 0.5.

Suppose then we want to make a light framework to support an aeroplane 50 × 25 cm. (See p. 561), we find that at 200 gms. per sq. M. the wooden frame will weight 25 gms.. If the specific gravity is 0.5, then the cubical contents of the wood forming the frame will be 25 ÷ 0.5 = 50 cu. cm. of wood.

The length of the framework on which to stretch and cloth for such an aeroplane, will be 150 cm. (See p. 561).

Hence the thickness, or rather the cross section of the wood forming the frame will be 50 ÷ 150 = 0.33 sq.cm. If then the wood of the framework should be 1 cm. wide, it may be 0.33 cm. thick.

150 × 1 × 0.33 = 50 c. cm.

That is, the frame may be made from a piece of wood 150 cm. long, 1 cm. wide and # cm. thick.

11

On Feb. 2, 1902, I weighed some specimens of silk — materials for dresses. See Home Notes pp. 10 and 11.

A A piece of red silk 315 cm. long and 49.5 cm. wide weighed 93 gms.

B A piece of black silk 1328 cm. long and 54 cm. wide weighed 998 gms.

C A piece of light blue silk for a skirt very impervious to air 376 cm. long and 27 cm. wide weighed 98 gms.

FLYING WEIGHT OF SILK FABRIC

A 60 gms. per sq. M.

B 139 gms. per sq. M.

C 97 gms. per sq. M.

On February 10 received from Ballauf a walnut frame for an aeroplane 50 × 25 cm.

This frame weighs 22 gms.

Flying weight 176 gms. per sq. M. of wing surface

Such a frame will do well for light framework. Allowing 100 gms. per sq. M. for the cloth of aeroplane surface, the flying weight of a kite constructed of aeroplanes stretched upon frames like the above, will only be 276 gms. per sq. M. of wing surface, leaving 124 gms. per sq. M. of wing surface available for heavy framework comparable to bony skeleton. The light framework is abundantly strong for this purpose.

12

1902, Feb. 19 Wednesday At 1331 Conn. Ave.

Mr. Zable obtained for me yesterday specimens of different materials to examine;— Two rods of bone and following kinds of wood: Ash, bass-wood, birch, cabinet-oak, California red-wood, cedar, cherry, chestnut, cypress, hickory, mahogany, quartered oak, poplar, maple, walnut, white pine.

Had slips cut from these, supposed to be ¼ inch square, but I find cross section is much less. The slips are from 28.7 to 29 cm. long, 0.7 wide, 0.7 thick. Today slips have been cut supposed to be #th inch square, but they are much more. I find they are practically 0.5 cm. wide, and 0.5 cm. thick.

1902, Feb. 20 Thursday At 1331 Conn. Ave.

Wooden sticks have been cut out each stick 29 cm. long 5 mm. wide and 5mm. thick. These slips were supported upon pieces of wood having a square cross section of 7 mm. — one support at either end — so that the slips were 7 mm. above the surface of the table as shown in the following diagram: —

The slips were then loaded in the middle as shown above by the weight W, to see how much weight they would support without touching the table. Where the weight recorded is less than 900 gms., the diameter of the weight pressing on the wood was 3.3 cm.; where it exceeded 900 gms. it was 8 cm., so that, in the former cases the weight was distributed over a portion of the wood only 3.3 cm. long; whereas with the heavier weight it was distributed over a portion of wood 8 cm. long. The following table shows the maximum weights supported by the sticks, without touching the table. They would not support 100 gms. more.

WEIGHT SUPPORTED WITHOUT TOUCHING TABLE.

Grammes Wood

300 Cedar

400 California Red wood

500

600 Cyress, Poplar,

700 Mahogany

800 Chestnut

908 Bass wood, cherry,

1008 Walnut

1108

1208 Ash, Birch, Cabinet Oak, Maple, White Pine.

1308

1408 Quartered Oak,

1508 Hickory.

13

On the following page I give a graphical diagram showing the relative stiffness of the different kinds of wood. The lines indicate by their length the weights supported by the slips of wood without touching the table.

14

The cedar slip weighed 3.5 gms., the hickory slip 5 gms. The hickory strip supported 5 times the weight supported by the cedar strip, and weighed itself less than one and one half times the cedar slip.

HICKORY SEEMS TO BE THE WOOD WANTED. Although quartered oak is not much inferior. A. G. B.

1902, Feb. 21 Friday At 1331 Conn. Ave.

The wooden strips mentioned in yesterday's notes, pp. 579 to 581 were made originally under instructions to make them #th in. square, but they turned out to be 5 mm. square. It is obvious, therefore, that they were not carefully or acurately made. They probably vary slightly in their dimensions and a very slight variation of thickness will make a considerable difference in the stiffness or resistance to bending. I do not therefore consider the table on p. 580, illustrated graphically on p. 581, as reliable in all its details.

I had some wooden strips made at Ballauf's, very carefully, and I think they can be relied upon as being accurately made according to instructions. One set consist of sticks 28 cm. long, 5mm. wide, and 2mm. thick. In the other set the sticks have the same length and width, but are 3mm. thick. I tested the stiffness of these sticks last night when loaded in the middle.

STRIPS 2MM THICK.

Dimensions of strip in mm. 280 × 5 × 2. Weight supported by strip without touching table in grammes, as follows:—

60 not 70 gms. Cabinet Oak, White Pine

70 not 80 gms. Quartered Oak, Walnut

80 not 90 " Ash, Hickory

90 not 100 " Birch, Maple

STRIPS 3 MM. THICK.

Dimensions of strip in mm. 280 × 5 × 3. Weight supported by strip without touching table in grammes as follows: — 15

240 not 250 gms. White Pine

250 not 260 " Walnut

260 not 270 "

270 not 280 " Cabinet Oak, Quartered Oak

280 not 290 "

290 not 300 " Hickory

300 not 310 "

310 not 320 “

320 not 330 “

330 not 340 “ Ash, Maple

340 not 350 “ Birch

These results do not tally with details relating to the strips 5 mm. thick shown on p. 580, but I think that greater weight should be afforded to the table on this page than to the toher on p. 580, because the strips in this case were very carefully prepared by Schneider at Ballauf's, whereas, the slips 5mm. thick were intended to be #th inch thick (about 3 mm.), and so bear evidences of inaccurate manufacture. Then again, the weights supported above are accurate to 10 gms. — that is the slips would not support 10 gms. more without touching the table, whereas in the result shown on p. 580 the results were accurate only within 100 gms. That is, the strips would not support 100 gms. more than the weights noted without touching the table.

The differences of stiffness between strips 2mm. thick and 3mm. thick is very remarkable, indicating that with thin strips of this character a very slight change of thickness makes an enormous difference in the resistance to bending.

If we take the weights supported by the 2mm. strips and compare them with those supported by similar strips 3mm. thick we find that although the thickness is only increased one half, the resistance to bending is increased about four times. The weight of each strip, of course, varies directly as the thickness. The resistance to bending seems to vary more nearly in even greater ratio. Compare the weakest wood noted — White Pine at 2mm. thick and 3mm. thick. The cube of 2 is 8; the cube of 3 is 27; the weight supported by the 2mm. strip was 60 gms.. If this should vary as the cube of the thickness, then: —

8 : 27 :: 60 : x

x = 202.5 gms.

The actual weight supported by the 3 mm., strip of White Pine is greater than this, namely 240 gms.

The error of observation is probably greater in the case if the thinner strip than the thicker.

As the weight of a strip increases directly as the thickness; and the resistance to bending in some greater proportion 16 (probably the cube) it is obvious that it would be advisable in the manufacture of a kite to use the thickest sticks consistant with proper flying weight.

I have decided to have some sticks of larger size very carefully made at Ballauf's. The results will probably be less liable to error than those obtained in the case of thinner strips. I adopt as my standard a stick 1 Metre long, having a cross section of 1 sq. cm. This size will also be of value in determining the specific gravity of the various woods, weigh the sticks and divide by 100, and you have the weight of 1 cu. cm. of the wood.

A. G. B.

1902, Feb. 22 Saturday At 1331 Conn. Ave.

Yesterday Mr. Zable secured specimens of wood, which were trimmed down at Ballauf's into sticks each 100 cm. long, 1 cm. wide, and 1 cm. thick. The following table shows the names of the different kinds of wood and their weights as ascertained by Mr. Zable.

Woods Alphabetically arranged

Ash 63 gms.

Birch 76 “

Hickory 83 “

Linwood 45 “

Maple 73 “

Oak (Cabinet) 77 “

Oak (Quartered) 62 “

Pine (White) 47 “

Spruce 43 “

Walnut 70 “

Woods arranged in the Order OF THEIR Weights

Weight in gms. Name of Wood

43 Spruce

45 Linwood

47 White Pine

62 Quartered Oak

63 Ash

70 Walnut

73 Maple

76 Birch

77 Cabinet Oak

83 Hickory.

RESISTANCE TO BENDING

Last night a stick of wood 100 × 1 × cm. was supported by its ends upon two other sticks, as shown above — so that — if straight — its lower surface should be 1 cm. above the surface of the table. The stick was then loaded in the middle by the weight W until the under surface of the stick touched the 17 table. The weights were increased successively by 50 gms. at a time. The sticks would not support 50 gms. more than shown below without touching the table. The experiment was tried four times with each stick — once with side A down; once with side B; once with side C; and last with side D down. The four observations in each case were added together and the mean taken. The results are given below: —

KIND OF WOOD

SIDE DOWN	ASH	BIRCH	HICKORY	LINWOOD	MAPLE	Oak Cabinet	OAK Quartered	PINE Wt.	SPRUCE	WALNUT.
A	300	600	700	600	500	350	450	550	550	450
B	450	900	250	450	550	350	400	500	500	550
C	400	900	400	350	450	200	350	550	400	550
D	400	600	950	550	450	200	450	650	550	500
Sum.	1550	3000	2300	1950	1950	1100	1650	2250	2000	2050
average.	387.5	750	575	487.5	487.5	275	412.5	562.5	500	512.5

In the following table these specimens of wood are arranged in the order of their resistance to bending. On the average they would not support a load of 50 gms. more than the figures mentioned below without touching the table.

Load in Grammes

275 Oak (Cabinet)

387.5 Ash

412.5 Oak (Quartered)

487.5 Linwood

487.5 Maple

500 Spruce

512.5 Walnut

562.5 Pine (White)

575 Hickory

750 Birch

The above results are shown graphically in the following diagrams:—

1902, Feb. 24 Monday At 1331 Conn. Ave.

Copied from Home Notes, p. 80, dated Feb. 22, 1902.

Both weight and strength should be taken into consideration. We not only want to use that wood which is strongest — but that which is strongest in proportion to its weight.

We are limited as to weight. If we can use one of the heavier woods by employing sticks of a certain sross-section — then we can use thicker sticks of a lighter wood.

For example: — 18

Spruce (100 × 1 × 1) weighs 43 gms. and supports 500gms.

Maple (100 × 1 × 1) weighs 73 gms. and supports 487.5 gms.

Here the lighter wood supports the greater weight without touching the table. But, suppose them equal — both 500 gms. — and suppose we can make a kite of maple sticks weighing 73 gms. then it is obvious that we can also make it of spruce weighing 73 gms. — and as the 43 gms. spruce was as strong as the 73 gms. — and as maple — the 73 gms. spruce will be very much stronger. If the—resistance to flexure varies at anything like the rate of the cube of the thickness, the increase of strength would be enormous. This much is obvious that we can use thicker sticks of spruce than of maple and hence get a much stronger framework with the same weight.

Make table showing ratio between weight and load as follows: —

Weight : Load :: 1 : x.

Copied from Home Notes, p. 81, dated 1902, Feb. 22.

Weight in gms. Load in gms. Ratio of Weight to Load Ash 63 387.5 1 : 6.15 Birch 76 750 1 : 9.87 Hickory 83 575 1 : 6.93 Linwood 45 487.5 1 : 10.83 Maple 73 487.5 1 : 6.68 Oak (Cabinet) 77 275 1 : 3.57 Oak (Quartered) 62 412.5 1 : 6.65 Pine (White 47 562.5 1 : 11.97 Spruce 43 500 1 : 11.63 Walnut 70 512.5 1 : 7.39

WOODS ARRANGED IN THE ORDER OF THE RATIO OF WEIGHT TO LOAD.

3.57 Oak (Cabinet)

6.15 Ash

6.65 Oak (Quartered)

6.68 Maple

6.93 Hickory

7.39 Walnut

9.87 Birch

10.83 Linwood

11.63 Spruce

11.97 Pine (White).

(Copied from Home Notes p. 82, dated Sat., Feb. 22, 1902).

Other qualities should be investigated, brittleness especially What loads will similar sticks support without breaking — That is an important point.

19

The above diagram illustrates graphically the table on p. 594 in which the specimens of wood are arranged in the order of the ratio of weight to load. The figures refer to specimens of wood 100 cm. long, 1 cm. wide and 1 cm. thick supported by their ends horizontally above the table at a distance of 1 cm. from the table. See drawing on p. 586.

The figures show the load supported by each stick without touching the table in terms of the weight of the stick. Thus, the stick made of cabinet oak would only support, without touching the table a load 3.57 times its own weight, whereas the stick of white pine supported a load of nearly 12 times its own weight (11.97).

The diagram shows that four of the woods tested were markedly superior to the others in the proportionate load they could sustain. These are, in the order named, white pine, spruce and linwood, and birch. Three of these, pine, spruce and linwood, are light woods, (the specimens weighing respectively pine 47, spruce 43, and linwood 45 gms.); and the fourth, birch, is a heavy wood (specimen weighing 76 gms.)

20

While it is true that a framework made of light wood of the same weight as a heavy wood would be of greater thickness (and hone hence in the cases considered of greater strength), it is also true that the thicker wood would offer greater resistance to the ai air than the thinner wood, so that, given two frameworks of equal ? weight, one made of specifically heavy wood, and the other of specifically light wood — than the specifically light framework would offer be more retarded in its passage through the air (if it constitutes the basis for flying machine) — or, if it constitutes a ?? kite, the wind would have more power upon it in increasing the element of drift — an undesirable element —

I am not at all sure that we should be guided entirely by the weight, I mean specific weight, of our materials, indeed I am inclined to think that where we have two specimens of equal strength (resistance to bending) the one that has least diameter or thickness is the one most suitable for our purpose, because it will resist the air least.

I have hitherto considered the strength of a specimen of wood to be demonstrated by its resistance to bending. Taking specimens of equal length and equal cross section supported horizontally at both ends and loaded in the middle — I have assumed that that wood which would support the greatest weight with the least bending was the strongest wood: and under this definition of strength birch comes out away ahead of the other woods. See diagrams p. 588. But there is another quality akin to strength — if indeed it does not more truly indicate strength — it is resis tance to breaking. It is conceivable that we may have a wood that will bend very little under a heavy load, and then snap suddenly in two. On the other hand we may have a wood which may bend under a comparatively slight weight, and yet not break under a heavier load than the other. Which is the stronger? Which is the more desirable characteristic for the wood of our framework?

Last night I took the strips of wood 2 mm. thick mentioned on p. 582, and attempted to bend them as shown in the following diagram:—

The details of the experiments are described in Home Notes pp. 83 to 86, under date Feb. 23. The birch strip was the only one the two ends of which could be brought any where near together without breaking. The other woods — even hickory — broke before they were bent into a semi-circle.

The two ends of the birch stick were safely brought together — but the strain was too great for the material and after a little while the stick broke while held in this position. The cabinet oak was very brittle, when bent a very little way it snapped into three pieces. The fracture of the pine indicates a brittle wood, 21 But the two fragments remained practically straight after the stick was broken. The fragments of the maple stick also seemed straight. The hickory did not break completely through, and the two unbroken portions appeared to be straight. One of the fragments of the birch strip was straight and the other bowed, thus retaining a set. The ash stick, also exhibited a slight permanent bend. One of the walnut fragments was also slightly deformed. There were no spruce or linwood strips 2 mm. thick, so breaking experiments were not made with these woods.

Of all the kinds of wood mentioned above it is certain that birch will stand the greatest bend without breaking.

I broke up the fragments of all the sticks with one hand into little pieces. They one and all (excepting birch) seemed weak. Birch is remarkably tough — can twist it into a sort of rope without breaking, and can bend it into a bow shape. When bent, however it <u>retains a set.</u> This feature is rather a dangerous one.— Distortion in the kite frame occasioning eratic behavior in the kite.

In my Hone Hotes, p. 86, dated Feb. 23, I conclude the notation of experiments as follows: —

“The properties of birch are somewhat remarkable. It <u>resists</u> bending better than the other woods, and <u>supports</u> bending better.

It takes more force to bend it — and bends more than the others before breaking. These are valuable qualities.

Although one of the heavier woods — its stiffness is so great that it compares well with the lighter woods in ratio of weight to load. (See p. 82).

While spruce, linwood, and pine, would give a greater resistance to bending for the same weight — they would have to be much thicker — and this would lead to increased air resistance.

I am a little doubtful about using the lighter woods — because we only get the strength desired — by incresing the thickness of the individual sticks — which will increase their resistance to the air — and thus lead to an increase of the element 'drift' — which is undesirable.

QUERY: — Given sticks of equal resistance to bending — are not those that have the smallest cross-sections the most desirable — as they will meet with less air resistance.

Go ahead and try a frame of B I R C H.

A. G. B."

22

In my Home Notes, pp. 87, and 88, I calculate the weight of a double frame of birch for a triangular frame of 200 cm. made of 25 cm. cells. Total weight would be 1140 gms., using a strips 5 mm. wide and 3 mm. thick, and cross bars 5 mm. wide and 5 mm. thick. This yields a flying weight of 339 gms. per sq. Metre for the light framework alone; or 439 gms. for the kite completed without any heavier frame — rather too great a weight for a light kite.

It would be better to calculate 50 cm. cells.

Using strips 5 mm. wide and 3 mm. thick, and cross bars 5 mm. wide and 5 mm. thick, the double framework for a 200 cm. compound cell could be made from 150o cu. compound cell could be made form 1500 cu. cm. of wood. If o of spruce at specific gravity .43, this would weight 646 gms. this would weight 645 gms.; if of linwood (sp.gr. .45) 675 gms. If of pine (Sp.gr. .47) 705 gms. If of bi r birch (Sp.gr. .76) 1140 gms.

The cloth surface of such a compound cell would be 3.3750 sq. Metres, and this enables us to ascertain the flying weight of the frame if composed of spruce, linwood, pine of birch.

WEIGHT OF FRAME

Actual weight in grammes Flying weight in grammes per Square Metre. Spruce 645 191 Linwood 675 200 Pine (White) 705 209 Birch 1140 339

If we allow 100 gms. per sq. M. for the cloth surface, the following would be the flying weights of kites made of the materials named without any other heavier framework.

FLYING WEIGHTS INCLUDING CLOTH.

Spruce 291 gms. per sq. M.

Linwood 300 “ “ “

Pine 309 “ “ “

Birch 439 “ “ “

It is obvious that a compound 25 cm. celled kite can be made of spruce, linwood, or pine which will carry a strong framework weighing 100 gms. per sq. M. and yet the whole be a light kite approximately 400 gms. per sq. M.

This cannot however be done with birch. Of course the birch kite, (which would weigh) somewhere about 539 gms. per sq. M. including the strong framework) would fly, but it would not prove to be a very light kite. Whereas, kites of spruce, linwood or pine would fly with hardly a breath of air and come down very lightly.

In my Home Notes at the bottom of p. 90, dated Geb. 23 I have made a preliminary calculation concerning the weight of a light frame of 200 cm. (50 cm. celled) kite, in which the triangular part would be made of wood 1 cm. wide and ½ cm. thick, with cross bars of 1 sq. cm. of spruce. I am surprised to find that the flying weight of the frame comes out as 172 gms. per sq. M., which is less than the flying weight of the 25 cm. celled frame (191 gms. per sq. M.). Am inclined to suspect some error. Will 23 make a more careful calculation of the weight of such a frame and it may be possible that we could make it of birch and have it come within our limits of weight for a light kite.

Am inclined to think that a 50 cm. cell is a good size to ado adopt for our unit cell. The wood forming the frame may be thicker than in the case of the 25 cm. cell, and this gives more room for scrwing together the parts. It will give solidity to the light framework. The smaller the unit cell adopted the weaker must be the sticks composing the light framework.

The heavy framework is intended to be strong enough to carry up a man: Would it be safe to have such a frame carried up BY EGG SHELLS. A.G.B.